THE TREATMENT OF RUPTURED LUMBAR INTERVERTEBRAL DISC BY VERTEBRAL BODY FUSION

III. METHOD OF USE OF BANKED BONE*

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THE USE IN SURGERY of bone and other tissues which have been stored by refrigeration was first demonstrated in 1912. Alexis Carrel[2] found that tissues preserved by cold storage remained alive and would grow when implanted in the dog from which they had been removed. Haas,[7] in 1923, showed that if bone is kept at room temperature the osteoblastic cells died in 19 hours. He said that the survival period of bone cells would probably be prolonged by preservation in cold storage. The clinical application of Carrel's experiment received little attention until 1942. Upon the important publication of Inclan[8] is based all modern work on preservation and use of bone by refrigeration. He demonstrated the viability of frozen bone, histologically, clinically and roentgenologically, and described its use in orthopedic surgery. This convincing work, however, did not stimulate the general acceptance and use of bone banks until 1947 (Wilson[12]). Since 1948 numerous articles have appeared by Bush,[1] Coley,[6] Weaver,[11] Reynolds and Oliver[10] and others, indicating that preserved bone grafts for use in surgery are gaining in popularity.

Bone banks are now in common use throughout the country and many hundreds of surgical operations have been performed successfuly with frozen bone. There are, however, still many skeptics who doubt that the bone cells in frozen bone remain alive, grow and reproduce new bone. This doubt and skepticism have been considerably reduced with the fascinating and most convincing recent work of Kien *et al.*,[9] who studied the viability of frozen bone grafts by means of radioactive phosphorus. Bone was removed from the dog's ilium and implanted in the tissues of the anterior chest wall. Two hundred microcuries of radioactive P_{32} were given intravenously, immediately. Grafts were then removed at varying intervals, simultaneously with control samples from the intact ilium, and assayed for radioactive phosphorus.

Grossly, the graft preserved by freezing was found to be intimately associated with the surrounding tissues within five to seven days and could not be removed without removing tissue. In three weeks' time, the sharp corners of the graft were smoothed out and a thin layer of new cortical bone appeared surrounding the graft. There was no variation in the behavior of the bone with the surrounding tissues, compared to the length of time the graft remained in storage. Bone preserved chemically or by boiling and implanted in tissues did not become associated with the surrounding tissue. After five weeks, it shelled out of a thick fibrous capsule, which had surrounded it, as dead bone.

The rate and amount of P_{32} taken up by the graft was used as a measurement of the metabolic activity of the bone. The revascularization and vitalization of the graft could thus be determined. It was

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found that the graft began to take up the P_{32} as early as the second day! The graft incorporated phosphorus at the same rate (but not the same quantity due to less vascularization) as the control bone! The length of time the grafts remained frozen before implantation did not alter their viability as determined by their ability to take up the radioactive phosphorus. The boiled or devitalized bone graft which did not become integrated or vascularized as part of the body was found to contain no P_{32}. The writer's clinical experience using frozen cadaver bone for spinal fusions since 1946 would bear out these experimental findings.

From 1939 to 1943 the writer, practicing neurosurgery on a small but densely populated and busy island (Oahu, T. H.), performed 162 operations for ruptured lumbar intervertebral disc. It soon became apparent that the simple removal of a herniated fragment of the ruptured disc was not the answer to the problem of low back pain and sciatica caused by this condition. In this five-year period, a recent review disclosed that nearly 75 per cent of these patients have returned to the office at one time or another with complaints of varying severity referable to their back or lower extremities. Fifty-one, or 30 per cent, of these patients have since been re-operated upon. Beginning in 1943[3] the writer began developing a new technic of spinal fusion. It seemed more physiologic that, to obtain fixation of one joint of the spine, a fusion of two adjacent vertebral bodies across the intervertebral space would be stronger and more efficient than an attempt to fuse the laminae and spinous processes across three or more joints. Accordingly, a procedure was worked out whereby, after removal of

FIG. 1

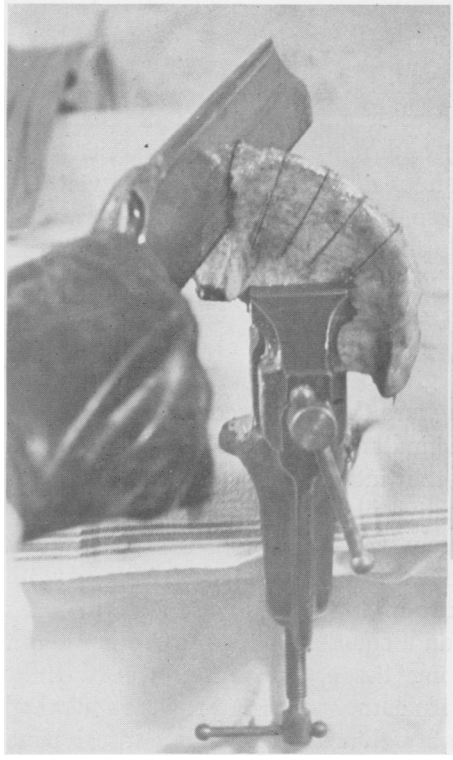

FIG. 2

FIG. 1.—Sawing ilium into "bone plugs."
FIG. 2.—Four or more "bone plugs" used to replace one ruptured intervertebral disc. The large chunk of bone is converted into bone crumbs to fill the interlaminar defect.

a part of the intervertebral disc including the cartilagenous plates, a full thickness bone graft obtained from the crest of the patient's ilium was driven between the bodies of the vertebrae. This procedure was successful from the beginning, in giving the patients lasting relief of their symptoms. Since 1944, almost every patient having a ruptured disc whom the writer has operated upon has been treated by

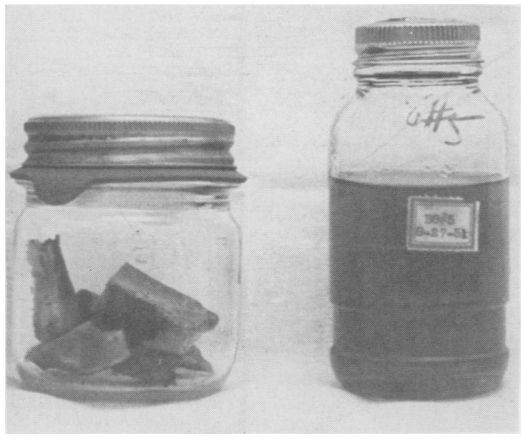

FIG. 3.—Small, half-pint wide mouth Mason jars with blood plasms used to store bone.

vertebral body fusion. The operative technic has been gradually improved over the years. The operation as it is done today consists of a subtotal removal of the intervertebral disc from both sides of the dural sac and replacing it with four or more large bone plugs. A mechanical fixation of the intervertebral joint is thus effected immediately.[4]

After doing this operation for two years, i.e., 1944 and 1945, the possibility of using cadaver bone for the bone grafts, as prescribed by Inclan,[8] occurred to the writer. Two factors were responsible for considering the use of bone other than that obtained from the patient. First, and most important, was the length of time required to perform the operation. At least three and a half to four hours were required to obtain the bone grafts from the ilium, do the laminectomy, remove the discs and complete the fusion. The second factor was the all too-frequent postoperative complaint by the patient of discomfort in the hip at the donor site. In 1946, with the aid of Mrs. Hazel Bond of the Honolulu Blood Bank, a method of preparation and preservation was worked out. Our bone bank soon became a reality. Our first concern, naturally, was the sterility of the grafts. The extreme danger of an infection from a non-sterile graft inserted between the bodies of the vertebrae can be readily appreciated. Our second concern, or rather consideration, was an attempt to keep the bone "alive," i.e., to preserve if possible the connective tissue cells and vascular bed within the bone upon which new capillaries could grow. This would hasten the growth of new bone into and across the graft. The technic which was worked out, and which has been used successfully for over five years is as follows:

OBTAINING AND PREPARING THE BONE

A suitable cadaver is chosen from which to obtain the bone. Bone from a young healthy individual, in whom death was sudden, by accident or otherwise, is preferred. Old people, who usually die of malignant tumor or infection (pneumonia), are unsatisfactory, and too, the cancellous bone from the aged is too soft and fatty. Our best source is from traffic fatalities. The body is prepared and bone removed exactly as for a sterile surgical operation. The skin is sterilized mechanically and chemically, and draped with towels and sheets. Sterile instruments, caps, gowns and gloves are used. Through a wide transverse incision, the muscles and fascia are stripped from the crest and the anterior and posterior surfaces of both ilia and, using hammer and chisel, as much of the ilium as possible is removed in one piece. The two large blocks of bone are immediately placed in a sterile basin with a lid,

and sealed on the outside with adhesive tape. It is delivered to the blood bank immediately or, if procured at night, placed in an ice box until morning.

STERILIZING, PRESERVATION AND STORING

The basin of bone is taken to the small closed "sterile room" of the bacteriologic department of the Blood Bank. Here again, with sterile technic throughout, including sheets, instruments, gloves and gown, the bone is cleaned of all soft tissue and cut up into the desired number and size of pieces. A small vise is sterilized, attached to the edge of the bench and used to hold the large pieces of bone (Fig. 1). With an amputation (or electric) saw, the iliac crest is cut into bone plugs for the intervertebral fusion. These plugs measure 3 cm. long and 1½ cm. wide, and are full thickness of the ilium (Fig. 2). The remainder of the bone is cut into several larger pieces 3 to 4 cm, across. Enough bone can be obtained from one cadaver to do three or four spinal fusion operations.

The jars used are one-half pint, wide-mouth Mason fruit jars. One-piece lids are purchased to replace the two-piece lids which come with the jars. These lids are chrome plated to prevent rusting. Rubber rings are also used to seal the jar (Fig. 3).

In order to accomplish our two premises, i.e., to assure absolute sterility of the bone, and to preserve the soft tissue elements of the bone if possible, a liquid medium was chosen. A liquid which could best keep the bone "alive" would be either whole blood or plasma (Inclan). Out-dated whole blood is the best solution but, when this is not available, blood plasma is used. Since blood is an excellent culture medium, the chances of detecting the slightest contamination are greatly enhanced.

Sufficient bone for one case, usually four or five plugs and one large chunk of bone are placed in the sterile jar and the blood or plasma solution added, the jars and lids having been previously sterilized by autoclaving. The lid is screwed tightly and the jar left at room temperature 72° to 80° F. for 24 hours. Blood agar smears and brain broth cultures are then taken from the solution and the jar placed in the ice box. The cultures are read daily for ten days. If the solution is found to be sterile after ten days, the jars are placed in storage. Jars containing solution and bone may be preserved either by freezing in a deep freeze (0 to 20° F.) or kept in a regular (blood) ice box at 36° to 42° F. From external appearance of the bone and the success of the fusions, one method of storage seems as good as the other. If the solution is not sterile, it is recultured before being discarded to rule out a possible false positive from contamination. We have kept bone in this manner for over six months and had the grafts "take" without difficulty. There is reason to believe that it could be preserved indefinitely.

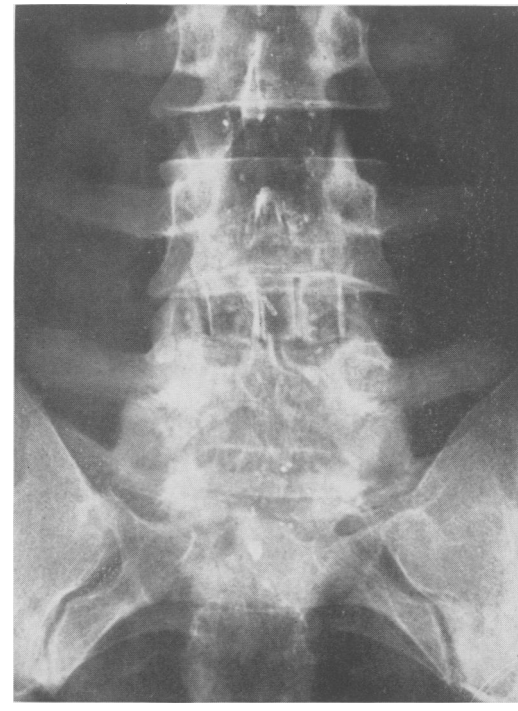

FIG. 4.—Roentgen ray of vertebral body fusion. The intervertebral disc replaced with three frozen iliac bone grafts.

USE AND RESULTS

On the morning of the operation, the bottle of bone is delivered to the operating room and placed in a warm water bath. The edge of the jar is painted with iodine and the entire contents poured into a sterile basin. The solution is poured off and the bone washed with saline solution. The grafts, ready for use, appear as "alive," red, and "raw" as when they were removed from the body. The large chunk of bone is nibbled up into small bone crumbs with a rongeur or bone mill. The plugs are fashioned to fit the intervertebral opening.

From 1944 to the present (1951) the writer has performed over 300 vertebral body fusions after removal of the intervertebral disc.[5] Of these, 68 operations have been done on 67 patients using banked bone entirely. Two cases were done early in the series in which the patient's bone was placed on one side of the spine and banked bone on the other side. By careful follow-up roentgenograms it has been impossible to detect any difference between the two. With banked bone, evidence of fusion appears just as early as the homogenous bone and goes on to just as strong a fusion. With this type of spinal fusion, i.e., between the vertebral bodies, where the patient's weight, in the upright position, wedges the grafts tightly together, roentgen ray evidence of solid fusion can be seen as early as two months. Almost all cases are well fused by three to four months, whether banked bone or the patient's own bone is used (Fig. 4).

There have been five wound infections in the 67 banked bone cases. Three of these were superficial wound infections—stitch abscesses, and one involved the bone grafts. All of these cleared with antibiotic therapy with no loss of bone. The patient went on to develop a solid fusion. In one patient, a 37-year-old nurse, the bone was infected. The wound had to be opened and all bone removed when no improvement was seen with drug therapy and irrigation of the wound after two weeks. Three months later, the patient was reoperated upon and the vertebral body fusion operation repeated, using banked bone again. The patient's wound healed by primary intention this time. She was discharged from the hospital on the tenth postoperative day without cast or brace and returned to her job as a nurse three weeks later. The percentage of wound infections using banked bone (3 per cent) were not as high as when the patient's own bone was used.

SUMMARY AND CONCLUSIONS

In an operation for fixation of the spine following loss of an intervertebral disc, the use of cadaver bone has proved to be both safe and effective. The dangers of infection have been eliminated by preserving the bone in a known sterile solution. The operation which took three and a half to four hours or longer to perform has been reduced to two hours or less! The patient's hospital stay has been shortened to a week or ten days, because there is but one wound to heal and availability of more bone makes a stronger fusion. Finally, the patient's postoperative discomfort, which often occurred at the donor site of the graft, is eliminated. The details of procuring, preserving and using cadaver bone for the operation of vertebral body fusion is described.

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THE METABOLIC RESPONSE TO SURGERY. Francis D. Moore, M.D., and Margaret R. Ball, A.B. Department of Surgery, Harvard Medical School and the Peter Bent Brigham Hospital, Boston, Mass. Published by Charles C Thomas, Springfield, Ill., 1952, and simultaneously in the British Commonwealth of Nations by Blackwell Scientific Publications, Ltd., Oxford, England, and in Canada by the Ryerson Press, Toronto. Price $7.50.

In this monograph, Doctor Moore has endeavored to bring together what is known of the response of the body to the trauma of surgery, with the object of presenting under one cover an understandable and workable concept for the practicing general surgeon of the complex chemical and physiological responses which his patients make as the result of surgery. To do this he has drawn for illustration on carefully documented and meticulously studied surgical cases from the surgical laboratories of the Peter Bent Brigham and Massachusetts General Hospitals, as well as on the work of others whose data have been recharted to conform to the methods of graphic presentation used.

The book begins with a discussion of the methods used in conducting a balance study, together with a careful explanation of the charting methods used and a definition of terms. The reader is urged to study this section carefully. It is necessary to an understanding of the subsequent data and discussions, and it illustrates as well some of the limitation of the method of balance studies.

The second chapter is devoted to illustrations of the response to a single surgical operation. The "classic" features of nitrogen, potassium, and weight loss accompanied by sodium and chloride retention in the immediate preoperative period followed by reversal in convalescence are illustrated, together with significant variations from this pattern. In the next chapter, "The Dissection," an attempt is made to separate the effects of immobilizatoin, starvation, and adrenal stimulus, and to combine these factors to reproduce the metabolic effect of surgery without the trauma of operation. That this can be done closely simulating the normal response to a major surgical operation is a most important observation and gives considerable information on the biochemical nature of the response to trauma.

There follows a description of the diminished response of depleted patients to surgery, and an experimental study of potassium depletion, with a discussion of the various modes of its production.

Of particular interest to the practicing surgeon is the chapter which deals with nitrogen balance and the fate of infused proteins and protein hydrolysates. A study of the periods of rejection and of utilization of protein hydrolysates by the surgical patient will result in far more discriminating use of these substances.

The book concludes with a summary chapter titled "Facts and Corrolaries." Here in concise terms are summarized the facts reported in previous chapters together with suggestions for the treatment of patients based on these facts. This chapter is a handy reference point in handling day to day problems. There is also a useful appendix which gives information on the construction of diets for surigcal patients and the content of intravenous fluids.

This book will be valuable to the medical student, the house officer and the practicing surgeon alike in providing a clear and carefully documented description of the metabolic response to trauma, together with practical suggestions for the daily application of this knowledge. In addition it is a reference of great value for those interested in a more detailed study of the problems of metabolism in surgery. HENRY RANDALL, M.D.